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EMBEDDING DIGITAL RIGHTS IN GEOVISUALIZATIONS

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Abstract

Geovisualization offers powerful tools and strategies to explore, analyze, and manage geo data. Interactive virtual 3D geo environments representing virtual 3D maps or 3D city models, however, raise the question how to control geo data usage and distribution. We present a concept for embedding digital rights into virtual 3D geo environments based on 3D geo documents, which are assembled by building blocks categorized into presentation, structure, interaction, animation, and control classes. The authoring system of 3D geo documents allows us to define permissions and constraints for all contained objects. In this way, authors define how their documents can be configured, personalized, reused, and redistributed. The strengths of the presented concept include the ability to integrate arbitrary geo data under a uniform software design and the ability to cope with privacy, security, and copyright issues. Possible applications include visual user interfaces for geo information, communication of geo information based on the publisher-subscriber paradigm, and geo data warehouse systems.

INTRODUCTION

An increasing number of software products based on geo data is emerging – strategies for interfacing, protecting, and controlling integrated geo data represent major challenges from a point of view of software engineering. Embedding digital rights in geo-visualizations represents an approach that offers a solution to this situation.

We introduce the concept of *3D geo documents*, which form a framework for visualizing 3D geo data while controlling their usage and distribution by embedded digital rights. 3D geo documents allow us to effectively communicate geo information for specific users and tasks by software products. By software product here we refer to any software system that contains geo data as central element to be displayed, manipulated and managed. Examples of those systems include interactive atlases, tourist information systems, environmental monitoring systems, radio network planning systems, traffic control systems, and city information systems. As a common characteristic, these systems are located at the end of the economic value-added chain of geo data. While most research in geo science, of course, is focusing on the individual parts of this chain, for instance geo-data acquisition, processing, and standardization, there are fewer concepts known about integrating 3D geovisualizations into software products.

As *prerequisites for deploying geo data* as part of software products they generally have to fulfill a number of properties:

- *Findable* – on the market, e.g., by geo data platforms and meta information
- *Available* – in terms of quantity and quality
- *Cost-effective* – in terms of price and licensing

- *Processible* – by application algorithms and systems
- *Compact* – in terms of internal and external memory encodings
- *Controllable* – in terms of copyright, data security, and privacy.

To integrate geo data as core element into a software product, there are manifold ways with respect to the technical implementation.

- *Integration by File System:* Geo data are managed as raw data stored in the file system.
- *Integration by Database:* Geo data are structured and managed by relational or object-based database systems.
- *Integration by Service:* Geo data are accessed using services that retrieve and manage geo data available at the service provider's site.
- *Integration by Visualization System:* Geo data are accessed via its graphical representation and manipulated through interactive user interfaces.

For data-based integration, common to the first three integration strategies, we can rely on standards such as format definitions, object definitions, and service definitions provided by OpenGIS and general data description languages such as XML and its derivative GML. They are well suited for specifying, integrating, storing, and distributing geo data, and they establish a basis for interoperability.

The crucial question underlying our approach has been whether there is a *generic software concep*t that would allows us to integrate geo data into any kind of software product such that the geo data can be easily explored, analyzed, and edited while being protected. The concept must be both *efficient* in terms of interactive computer graphics and storage requirements as well as *flexible* in terms of configuration and adaptation to individual software products. In general it will not be possible to build in a geo information system in a (possibly "lightweight") software product due to technical issues (software complexity, administration) and economic issues (licensing and costs). Therefore, our solution has been based on integrating geo data into software products by a generic, powerful geovisualization system.

In a typical software-product development process, once geo data have been found that fulfill availability, cost-effectiveness, and processability the question arises how that geo data can be compactly integrated, interfaced, and controlled. 3D geo documents provide a solution for these tasks.

3D geo documents act as containers for collections of related geo data, offer presentation and interaction functionality, and allow developers to include application-specific functionality. In 3D geo documents we specify digital rights by constraints and conditions of geo data usage, that is, we define the degree of reusability and "openness" for each individual building block. Through this, the author can control usage, distribution, and personalization of 3D geo documents. In a sense, 3D geo documents act as intelligent geo data containers with built-in controlled user interface.

3D geovisualization as a main technique to operate and communicate geo data implies a large bandwidth of possible uses – in particular, if not only an author but also a user can configure and actively define the various steps in the visualization pipeline (Fig. 1), that is the filtering stage (data selection), representation stage (data encoding and transformation), and presentation stage (data rendering and display).

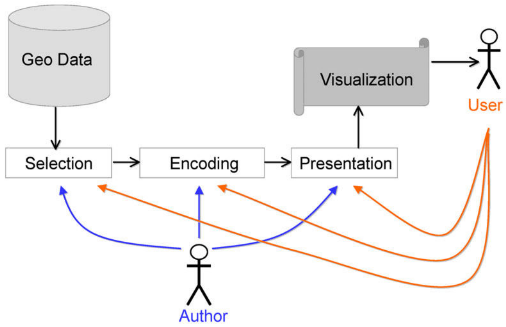

Figure 1: General visualization pipeline (Spence, 2001). Generally, interactive visualization allows users to configure the whole pipeline.

DESIGN OF 3D GEO DOCUMENTS

3D geo documents represent geo information by means of virtual 3D geo environments such as virtual 3D maps and virtual 3D city models. They define presentation, interaction, animation, editing, and distribution capabilities of contained geo data. As fundamental components they typically require digital terrain models, geo-referenced raster data, and geo-referenced vector data.

For the software design we have developed a systematic collection of 3D geo document classes. The term 'class' is used in the sense of object-oriented software modeling, that is, by class we mean "[…] a description of a set of objects that share the same attributes, operations, methods, relationships, and semantics." (OMG, 2003) A 3D geo document is created by constructing and assembling objects of these classes according to the specific needs of an application. Figure 2 illustrates our implementation of the authoring system for 3D geo documents.

The collection of 3D geo document classes in our approach can be subdivided into five main categories:

- *Presentation Classes*: They specify objects that define the visual presentation of geo data such as level-of-detail terrain models, 3D city geometry, terrain information layers containing raster data and vector data, 2D symbols and labels etc.
- *Structure Classes*: They specify objects that structure the collection of objects within a single 3D geo document. In particular, they provide folders to hierarchically arrange objects, and categories to attribute additional semantics to objects.
- *Interaction Classes*: They specify objects that define how users can interact with the virtual environment. We distinguish between 3D navigation techniques such as virtual trackballs, virtual pedestrian navigation, and flight navigation, and action objects that define how objects react to events such as calling application-specific routines or executing hyper links.
- *Animation Classes*: They specify objects that define time-dependent behavior of presentation objects. For instance, a visual bookmark records a camera setting and can perform a camera animation to fly to the recorded position at a later point in time.
- *Control Classes*: They specify objects that define constraints and conditions for objects contained in 3D geo documents. Above all, constraints refer to navigation

capabilities; for instance, minimal and maximal camera heights across the terrain can be defined as virtual surfaces used by collision detection. Constraints also can restrict individual object properties, for instance, a constraint could define that a terrain information layer cannot be disabled. Another example represents the watermark, a transparently displayed image that cannot be removed one the document is distributed.

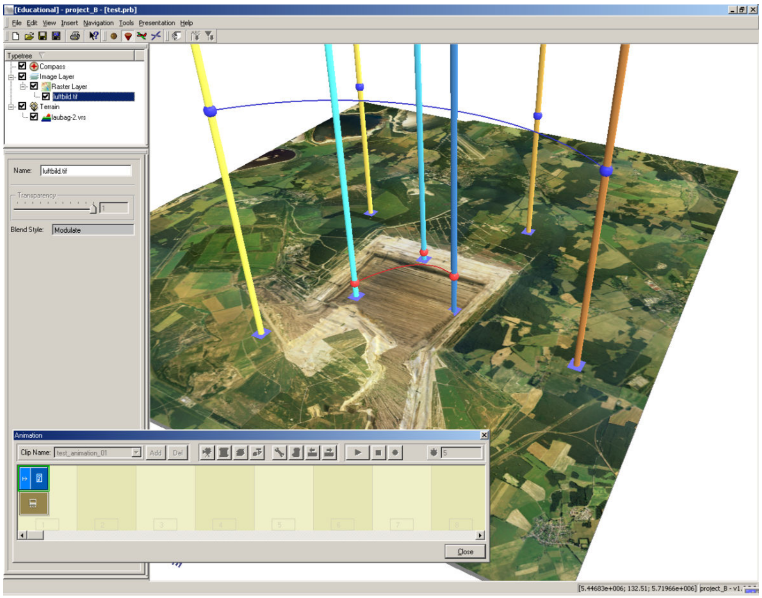

Figure 2: User interface of the 3D geo document authoring system.

Detailed technical information on 3D geo document classes can be found in Döllner and Kersting (2000). To create manually a 3D geo document, the user can interactively construct objects using an authoring system (e.g., LandEx Studio by 3D Geo, 2004). To create automatically 3D geo documents, the contained objects can be specified in an XML –based language. These XML specifications are processed by a 3D geo document engine, which constructs and assembles the corresponding objects and stores the resulting 3D geo document for later use.

ENCONDING OF 3D GEO DOCUMENTS

The technical representation of 3D geo documents and their contained objects, that is, the encoding, is based on an entire object-oriented representation and concentrates on an efficient internal computer graphics representation as well as on flexible mechanisms to embed "digital rights".

Computer Graphics Representation

The most important purpose of 3D geo documents is to provide interactive 3D visualization. For this, the presentation objects are optimized towards an efficient 2D and 3D computer graphics encoding of data. The computer graphics representation aims at:

- Transforming geo data to be visualized in an efficient computer graphics encoding.

- Extracting geo data only for actually required areas and at the resolution needed by users.
- Compressing computer graphics data with or without loss of precision.

In real-time computer graphics, there is a growing number of efficient algorithms for encoding and rendering of 3D graphics data; Akenine-Möller and Haines (2002) give a general introduction of real-time graphics. In 3D geo documents digital terrain models are transformed into level-of-detail representation that allows for view-dependent refinement of complex meshes. Level-of-detail 2D texture pyramids, together with a hardware-supported texture compression scheme, encode and compress geo-referenced raster data. Note that in most software products it is not required to reproduce the original geo data – the main purpose is to visualize geo data. For this reason, we take full advantage of computer-graphics representations to implement presentation classes.

Object-Oriented Representation

As a general software engineering technique to protect the data, we wrap geo data into presentation objects. Hence geo data can only be accessed and used by the software interface defined in the corresponding classes of these objects. In object-orientation, this feature is known as data encapsulation and leads to more stable, more reusable software designs.

The classes also define persistency functionality used to store and retrieve 3D geo documents. In our implementation, we developed two serialization strategies: one based on a binary format, the other based on an XML description. The first is used for compactly storing geo documents, the latter is used to transparently store 3D geo documents.

The binary serialization allows us to store a whole 3D geo document as a "black box". All contained objects are serialized, and the whole network of objects, including data and object associations, are transformed into a single byte stream preserving all relationships and object states. In this form, 3D geo documents become self-contained digital documents. In addition, the binary serialization implicates a weak type of encryption because its encoding is exclusively defined by internal object structures; it would be practically impossible to precisely extract the original geo data from a byte stream.

Digital Rights Representation

The term 'digital rights' and related management systems are defined in the scope of information technology as follows: „Digital Rights Management (DRM) systems restrict the use of digital files in order to protect the interests of copyright holders. DRM technologies can control file access (number of views, length of views), altering, sharing, copying, printing, and saving. These technologies may be contained within the operating system, program software, or in the actual hardware of a device." (EPIC, 2004) This definition also applies to digital rights in 3D geo documents, whereby we want to control object access instead of file access since we are operating on serialized object networks.

In 3D geo documents, digital rights can be embedded in two ways: digital rights represented by control classes and digital rights defined by object permissions. Examples of control classes include:

- Minimal and maximal viewing distance, measured from above the terrain surface to ensure that the graphics resolution does not become insufficient.

- Camera orientation restrictions, which can limit all configurations of a virtual camera with respect to the terrain surface.
- Collision detection with any 3D geometry contained in a 3D geo document.

Examples of permissions include:
- Permission to export contained geo data.
- Permission to import geo data by new presentation objects.
- Permission to enable and disable contained presentation, interaction, and animation objects.
- Permission to add and remove objects of specific presentation, interaction, and animation classes.
- Permission to open to the document by the authoring system.

The maximal protection applicable to a 3D geo document consists in protecting all contained objects together with disabling all navigation techniques so that users can only get a static image of the virtual 3D geo environment. The minimal protection allows all users to completely edit the whole document, that is, to freely insert and remove objects. To illustrate further the scope for design, we outline a few possible configurations:
- Distribution 3D geo documents with exactly one navigation control, which allows users to zoom in and out from a defined 3D geo-referenced terrain point.
- Distribution of 3D geo documents with view-plane buttons representing all allowed actions. Examples include a view-reset button, a button to switch between two or more navigation controls, buttons to enable and disable thematic terrain information layers, etc.
- Distribution of 3D geo documents with built-in analysis tools, for instance, to interactively measure polylines and polygonal areas or to report terrain height or thematic values.
- Distribution of 3D geo documents, which allow users to mark 3D positions by 3D labels and path objects and to store them as personal data inside the 3D geo document.
- Distribution of 3D geo documents, which allow users to record own fly-through frame sequences.

APPLICATIONS OF 3D GEO DOCUMENTS

Embedded digital rights in geovisualizations based on 3D geo documents manage copyrights, security or privacy issues. Thereby, they also enable flexible business models and can be used to implement various product types and application scenarios.

Interactive 3D Geo Environments

First of all, 3D geo documents represent interactive 3D geo environments and provide manifold visualization techniques available through the various presentation, interaction, and animation classes. Above all, geo data can be interactively explored and analyzed. The graphics-oriented architecture also allows us to integrate geo data of different formats within the same virtual environment – an interesting level for interoperability since many technical issues are bypassed compared to the integration at the data modeling level.

3D Geo Documents as a Geovisualization Subsystem

3D geo documents can be utilized as user interface systems for geo information. They allow application developers to integrate geovisualizations in their own software systems as a reusable subsystem (Fig. 3). For this purpose, developers use the 3D geo document application programming interface (API), and link the 3D visualization system to the user interface of the application. The application can construct, manipulate, and perform any 3D geo document operation while using the visualization subsystem for interactive display.

3D geo documents in this scenario are used as high-level software components providing virtual 3D geo environments. They encapsulate all computer graphics techniques and, therefore, help to manage complex software systems. We have integrated successfully the LandEx system as a subsystem into a radio network planning system of a major telecommunication company. 3D geo documents are used to represent geo data and geo objects of a complex radio network, and can be interactively explored, analyzed, and edited.

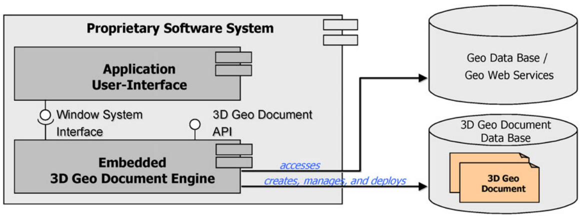

Figure 3: Integration of 3D geo documents as geovisualization subsystem.

Publisher-Subscriber 3D Geo Documents

The publisher-subscriber paradigm can be implemented for geo data using 3D geo documents in a straightforward manner (Fig. 4). The publisher (or author) defines the contained geo data and the forms of their presentation, interactivity, and animation, and finally sets up digital rights and controls. Once finished, the 3D geo document is serialized as a black-box. In this form, it can be distributed by any digital media such DVD or Internet. Subscribers (or users) can activate the black-box 3D geo document by a corresponding viewer application; the serialization can include even this viewer application so that the black-box 3D geo document becomes a stand-alone application. The viewer application takes care of guarding digital rights.

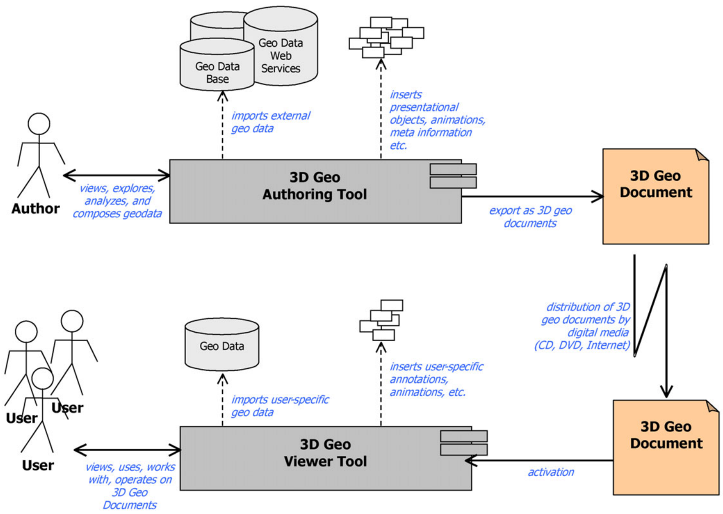

Figure 4: Illustration of 3D geo documents within the publisher-subscriber scenario.

3D Geo Documents for Geo Data Trading

In this geo-data warehouse scenario (Fig. 5), 3D geo documents serve as containers of 3D geo data requested by customers. Based on an XML description, a server process is assembling 3D geo documents on demand; as output it is delivering the (self-contained) 3D geo document as "black box". Note that customers don't get "the geo data" – they get an interactive application that is visualizing the geo data. Using digital rights and controls, the geo data vendor can implement different business models and offer varying degrees of access to the geo data.

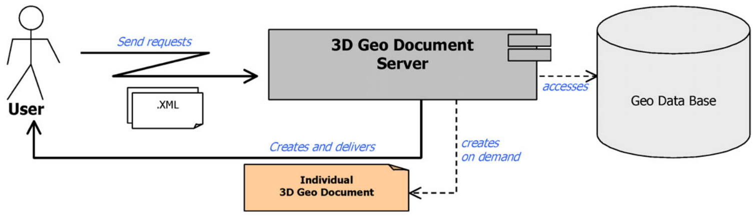

Figure 5: Geo-data warehouse scenario based on 3D geo documents.

CONCLUSIONS

The concept of 3D geo documents based on a fine-grained object-oriented and graphics-oriented representation of presentation, interaction, animation, structure, and control classes offers a generic solution for embedding digital rights into geovisualizations. This concept is targeted towards software products that need to integrate geo data as core elements. It strengths include the ability to integrate arbitrary geo data under a uniform paradigm, the virtual 3D geo environments, and the ability to cope with privacy, security, and copyright issues. It also offers authors of 3D geo documents manifold possibilities to design geo-based software products and user interfaces.

In future work, we will address the aspect of collaborative visualization. Currently we are developing an extension that allows users of related 3D geo documents to communicate with each other across a network and to synchronize specific user activities.

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